The prospects of delivering the electric vehicle charging infrastructure to support Scotland's 2032 transport electrification targets

Aaradhya, Chaitra; Thomson, Craig S.

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The prospects of delivering the electric vehicle charging infrastructure to support Scotland's 2032 transport electrification targets

Chaitra Aaradhya
Towner and Townsend, Bristol, UK
(email: CAARAD200@caledonian.ac.uk)
Craig S Thomson,
Glasgow Caledonian University, Glasgow, UK
(email: craig.thomson@gcu.ac.uk)

Abstract

Rapid urbanization has put a considerable strain on the resources and environment, thereby adversely impacting sustainability targets and climate change objectives. In a global context, cities are being transformed to adopt sustainable measures by integrating cleaner energy generation and smart mobility solutions. Zero-emission based Electric Vehicles (EVs) offer a huge opportunity to improve air quality in cities by reshaping the current carbon-intensive transportation infrastructure, thus benefiting the health, environmental and quality of life for its residents. In 2017, the Scottish Government adopted an ambitious target of phasing out new fossil-fueled vehicles and replacing them with Electric Vehicles (EVs) by 2032 and 8 years ahead of the UK government targets. This research focused on identifying infrastructure challenges associated with setting up of electric charging infrastructure required for fueling EVs and whether current government policies were adequate for meeting Scotland's 2032 transport electrification targets. Furthermore, the role of industry, local authority and end-user stakeholders in bridging the identified gaps was critically analyzed to review the preparedness of Scotland in meeting the above targets. The development of an EV market presents an opportunity for Scotland to become a technology leader ahead of other countries. However, as the technology is evolving at a fast rate, it was quite difficult to predict the future with accuracy. It is hoped that by addressing the current policy gaps, providing adequate funding support for technology adoption, infrastructure deployment and promoting stronger stakeholder engagement will help change the perception towards embracing EVs. The key challenge facing policymakers will be to identify the correct approach and roadmap to phasing out fossil-fueled vehicles and replacing them with EVs. Achieving the milestone for Scotland will be more tedious, but could offer opportunities for exporting of innovation-based EV technologies globally.

Keywords: Smart Cities, Zero Emission Electric Vehicles, Infrastructure deployment, Stakeholder engagement

1. Introduction

1.1 Background

Cities and towns around the world are facing unprecedented challenges. The pace of urbanization is increasing exponentially due to migration (or) births. The world urban population has grown rapidly from 746 million in 1950 to 3.9 billion in 2014 (UN, 2014). It is projected to surpass 6 billion by 2045, while the population share in urban areas is expected to increase from 54% in 2014 to 66% in 2050. In addition, issues such as climate change and other environmental pressures have put more strain on the resources and development of urban cities and towns. Therefore, urban areas now have an urgent need to become self-sustainable in order to handle such pressures seeing the emergence of the Sustainable Cities movement in the early 1990's. Roggema (2017) introduced six design principles around which a sustainable city can be delivered "a design in which cycles are closed, redundancy is built-in, anti-fragility is created, citizens are seen as (design) experts, the landscape is used as the basis, and innovative, rule-breaking designs are developed". Sustainability and Climate Change targets are linked and in the UK ambitious targets are set through the Climate Change Act 2008 at a reduction by 2050 to a least 80% from 1990 levels. Such reductions call for cities to become progressively "smart" and adopt necessary measures to meet stringent sustainable targets levied by pledges and legal commitments. The 'Smart cities' agenda has emerged in the last decade with its focus on innovation promoted by technology and data, with a view to contributing to progress the delivery of sustainability and climate change objectives. Transportation has emerged as a key focus for aligning the delivery of both Sustainable and Smart Cities agenda's.

1.2 Transportation and Sustainable Cities

Transportation is a key context with the EU setting a target to decarbonize the transportation sector by 60% by 2050 from 1990 levels (Spottle et al., 2018). Recent years have also seen the contribution of transport to poor air quality in our cities with recent research claiming a total cost of £2.7 billion through its impact on productivity (UK Government, 2017). A report from World Health Organization (WHO) indicated that the number of pollution zones in Scotland rose to 38, while Glasgow ranked higher than London in terms of pollution levels of NOx and particulate matter (Dalziel, 2017; Stanners, 2017). It is recognized that the UK government policies were now to blame for promoting diesel-powered vehicles in the early 2000s. Although diesel produced less CO2 emissions than petrol, it emitted greater quantities of NOx and particulate matter, thus damaging local air quality (Rosenbaum, 2017). This action directly contributes to an increase in health issues for the general public, costing the exchequer nearly £6 Billion annually in health care costs and an estimated 40,000 early deaths related to air pollution in cities (Brand and Hunt, 2018).

Low Emission Zones (LEZs) are increasingly being adopted as an instrument of choice globally to limit harmful impacts of CO2, NOx and particulate matter emissions. In 1996, Sweden was the first country to introduce LEZs and currently, there are over 250 LEZs across 15 European countries. The Scottish government was forced to act for two main reasons: 1) it did not figure in the list of progressive EU nations investing in LEZs and reducing air pollution measures in cities and 2) it was obliged to define its own emissions reduction target date in compliance with EU safety standards by 2030, after having exceeded norms for NO2 pollution for Glasgow in 2010 (UK Government, 2017). The UK and Scottish Governments, and Glasgow City Council took pro-active steps to limit the growth of all fossil-fueled vehicles, and in September 2017, Scotland's first low emissions zone was proposed for Glasgow city centre to be operational by the end of 2018. Although the trial phase is directed at local service buses, the plan was to extend it to other vehicle types by the end of 2022.

1.3 Transportation and Smart Cities

In recent years, the use of Plug-in Electric Vehicles (PEVs) (or) Plug-in Hybrid Electric Vehicles (PHEVs, which will henceforth be referred as PEVs) as Ultra Low Emission Vehicles (ULEVs) is increasingly being deployed as a solution for reduction of air pollution and global warming (Spottle et al., 2018). Technology reviews highlight that PEVs have the ability to increase energy efficiency,

combat toxic emissions, thereby significantly reducing the dependency of fossil fuel in the transportation sector (Wikstrom et al. 2016). EU Directive 2014/ 94/EU sets out the regulatory measures for increasing the number of charging points by promoting uptake of PEVs, along with developing alternative fuels infrastructure (hydrogen, biofuels and natural gas).

In this early stage of PEV market development, most countries around the world have adopted the demand-oriented approach to rolling out the charging infrastructure (Spottle *et al.*, 2018). A point of consideration is that the build-up of charging infrastructure and uptake of PEVs are correlated and represents a chicken and egg scenario. Secondly, charging point technology is evolving and the terminologies used in this sector have got people confused regarding the types of charging stations available (Griffiths, 2017). There has been progress in European countries like Netherlands, Germany, France, UK and Norway accounting for more than 10,000 public charging points in place (Spottle *et al.,* 2018). However, a survey conducted by HSBC in the UK found that the ratio of charge points currently available per people is around 17000:1. Another statistic indicated that a total of 173 new publicly-funded charge points were installed in 2017 when compared with 47,000 registered PEVs during the same year (Donnelly, 2018). The key challenges affecting the EV charging infrastructure roll-out in populated city dwellings include the limited availability of additional electricity, scattered location of EVs, installation and operational cost efficiency requirements and scalability issues. Suonsivu et al. (2017) concluded that the risks of investing in a faster-evolving technology, high maintenance costs and future upgrade needs would translate to steeper charging costs and outweigh the economic benefits of EVs unless economies of scale were achieved. Donnelly (2018) was critical of the fact that nearly three-quarters of the UK population had limited access to publicly-funded charge points, he highlighted some positives, which included Scotland's public funded PEV Infrastructure as well developed when compared to England and Wales contributing to the 743 charge points for every 7.12 people. ChargePlace Scotland represents a database of public electric vehicle charge points available across Scotland. The network was developed with grant funding awarded to Local Authorities and assists PEV users to locate their nearest PEV charge points and provides real-time info on the type of charger installed (i.e., slow charger, fast charger or rapid charger) and current availability.

1.4 Role of governance to deliver necessary infrastructure

In September 2017, the Scottish government proposed an ambitious target to phase out new fossil-fueled vehicles and replacing it with PEVs by 2032, 8 years ahead of the UK government targets. The announcement for a Greener Scotland attracted a great deal of media attention due to its ambitious outreach to implement PEVs and make A9 route in Scotland fully electric-enabled road. The UK Government's 2040 target announced in July 2017 was based on a manifesto commitment for nearly the entire fleet of fossil-fueled vehicles to be zero emission by 2050. Although the above milestone dates seem rather challenging, change is already on the way. There are already over 150,000 PEVs on UK roads and in the next 5 years may see an exponential increase to over 1.5 million as predicted by automotive experts. Electric vehicle sales are rising steeply in the UK, with new registrations of plug-in cars increasing from 3,500 in 2013 to more than 145,000 by April 2018 (Kirkcaldy, 2018). As of 2017, there were around 2,833 public PEV charging points across UK (including 1,133 in Scotland), way behind their European counterparts such as France with 11,987 points and Germany with 7,937 (Lea, 2018). Globally, it can be observed that there is a lack of electric charging infrastructure to match the demand for car sales of PEVs. Furthermore, Dave (2017) was of the opinion that although the PEV charging infrastructure market is still in an evolution stage, it was developing at such a rapid rate that it would be very difficult to predict what the future holds in terms of challenges and opportunities, with any great accuracy.

The UK National Grid (2018) highlighted that implementing PEVs and replacing all fossil fuel vehicles presents a serious challenge to electricity generation, as the peak electricity demand could add an additional 50% to the current peak of 61 GW (equivalent to 10 times the total power output of the £20 Billion Hinckley Point C Nuclear power station under construction). This coupled with the closure of dirty coal power stations throughout the UK under commitments to the global climate

change accord showcased a precarious situation, as the UK would become more reliant on imported electricity, thus raising a range of wider strategic questions.

2. Rationale and aim

The research explores whether or not the challenges facing the realization of electric charging infrastructure in Scotland by 2032 can be achieved by the current government policies. Recent momentum provided to this agenda from both private and public sectors has stemmed from the need to address air pollution by adopting low carbon technologies like PEVs. The Scottish Government's ambitious target of phasing out new petrol and diesel vehicles by 2032 provided a platform to review the planned roadmap and stakeholder engagement plan to achieve the set targets. The technological evolution of PEVs has come a long way. The initial skepticism put forth about PEV's is slowly changing and that there has been a steady increase in the uptake of PEVs over the last 5 years. Around 11 million PEVs are expected to be on the UK roads by 2030 and the charging infrastructure is poised to become a critical enabler for the adoption of PEVs (National Grid, 2018). The above action has resulted in the UK government taking strong actions to plan a policy framework for the deployment of PEV's and develop the required charging infrastructure to meet the rising demand.

Although there have been a number of previous studies devoted to the deployment of electric charging infrastructure, they were conducted at a time when the PEV manufacturing companies were still in the process of experimenting and innovating with the technology (including testing the reliability and practicality of storing electricity in a battery) at hand. Since there has been remarkable progress by EV sector in terms of demonstrating the technology readiness and performance levels over the last decade, thus providing credible assurance to people to consider owning an Electric Vehicle. This research seeks to explore whether the widening gap between the electric charging infrastructure currently available compared to the uptake of PEV's can be resolved and whether our planning for the required infrastructure is sufficiently addressing this gap as it has the potential to limit the current and future demand of EV's. Therefore, it seems plausible to research further into how the infrastructure challenges associated with the electrification targets will be achieved by 2032 in Scotland. Secondly, there is a need to identify whether current regulatory policies can bridge the gap between charging infrastructure and PEV's and if the number of available charging points will be adequate enough to cope with the surge in demand. A key aspect is to consider whether the governance structures adopted in Scotland are helping the preparedness to meet the 2032 transport electrification targets.

Glasgow- a case study

Glasgow is a signatory to the EU "Covenant of Mayors" and is implementing a Sustainable Energy and Climate Action Plan" (SECAP) by engaging in the EU funded STEP UP project. Some of the observations suggest that Glasgow is much polluted due to its high energy consumption, mainly based on fossil fuels (Understanding Glasgow, 2017). In 2014, 38% of Glasgow's energy consumption was in the 'Industrial & Commercial' sector, 35% was attributed to domestic consumption and 27% was in the 'Transport' sector. Over the same period, CO2 emissions were reduced by 27%, meaning that Glasgow was above EU targets in this respect, but below the UK, Scotland and SECAP target. It should be noted that this decrease was mostly related to the transition to renewable energy achieved in two year periods (2008-2009, 2013-2014). To meet the targets for 2020 and 2030 Glasgow needs to boost its use of renewable energy and increase the efficient use of energy. In fact, the energy consumption reduced by 17% in the aforesaid years with the lowest reduction (~3%) achieved in the transport sector, thus signifying the challenges ahead if electrification targets are to be achieved by 2032. The transport sector has therefore become a significant policy for the future planning of the city, with the added driver being the poor health statistics related to air quality and wide issues related to improving conditions for promoting active travel. The electrification of transport requires consideration of renewable energy generation but also the infrastructure requirements associated with charging points for electric vehicles.

3. Methodology

The research follows an interpretivist approach starting with a literature review to identify research questions and themes to explore through a series of thematic interviews. The interviews seek to understand the current challenges facing the industry around three groups 1) those delivering the infrastructure, 2) city council and 3) end users towards electrification of the transport sector, and answer why/what/how/when key performance indicators will be achieved. The key focus is to explore whether the current target of 2032 is realistically achievable? The literature review on EV Infrastructure suggested that there is a huge gap between the infrastructure needs for electric cabling/charging points and the uptake of electric vehicles with little clarity on the policy framework and funding support from the government. The interviews focused on the key elements such as standardization, range anxiety, upfront costs and grid constraints. Stakeholders were identified using snowballing techniques with ten interviews with those at the heart of delivering electrification of our transport infrastructure in Glasgow. Transcripts were analyzed using thematic analysis exploring the themes and any emerging during the interviews. The observed views assist the author in determining whether any change has taken place (or) starting to take place since the introduction of various policy guidance reports published by Scottish Government, such as 'Switched on Scotland' and 'Switched on Scotland- Phase Two'. The interviews explored four key themes.

4. Findings and discussion

4.1. Infrastructure Challenges

Standardization of charger systems

The literature review revealed that charging system technologies vary greatly creating problems related to standardization and the need to duplicate for different user requirements. The stakeholders in the interviews revealed that they were aware that this was a problem but was an issue which was being considered in the infrastructure planning. The uptake of Type 1 based CHAdeMO charging standard developed for the Japanese market found few takers as it did not meet the requirements of Society of Automotive Engineers (SAE). SAE developed its own charging system standard (combo-charging system), while different countries like USA and China followed suit and developed their own standards. From the industries perspective, interviews revealed that a lack of universal EV charging protocols and certification was seen as the biggest hurdle from an industry point of view. It was observed that the shift towards owning had accelerated as battery technologies were coming of age, but the charging infrastructure was not aligned yet to the demand requirements. Industrial stakeholders were concerned with a rising number of disparate suppliers (with incompatible charging hardware and systems) which could result in health and safety concerns, as well as creating confusion amongst end-users, thus negatively impacting the EV market. This was a problem observed by the end users who felt that the lack of universal charging infrastructure was contributing to increased stress levels in locating a compatible charger in real-time. A concern emerged for those wishing to invest in EV that with the variation of charging technology that early adopters may end up with technology which becomes obsolete and that this was an unacceptable risk. A full consensus was reached across all stakeholder types as the respondents agreed that there should be a globally accepted standard for charging systems along with an adequate number of charging stations in close proximity were the immediate needs of the day.

Grid constraints

From the perspective of those stakeholders involved in delivering the infrastructure there was real concern that the current capacity of the electrical grid is not sufficient to cope with the additional capacity to be added with EV rollout. Divergent views were observed regarding required capacity ranging from an additional 10 GWe to as high as 50-60 GWe to the current peak UK electrical demand of around 60 GWe. Similar inconsistencies were reported in the literature too. The industrial stakeholders all felt that the UK National Grid was best placed to address the additional capacity required for EV roll out as it provided stability but that this would still require consideration as integrating renewables and localized low carbon electricity generation through smart grids would present stability challenges. An agreement was found that other low carbon fuels like hydrogen and bio-methane should be explored to support attaining the 2032 objectives, however user stakeholders

expressed concern over this technology with a perception that it can cause leaks and explosions.

Scottish and Southern Energy (SSE) has been partnering with various third parties in support of EV future and one such initiative was to monitor the impact of high concentrations of charging activity on the local grid through the 'My Electric Avenue' project. My Electric Avenue project was designed to understand the impact of clusters of EVs on low voltage feeders, trailing a new demand control technology, 'Esprit' to manage cable stress and avoid network overload, thus saving costs and disruption to customers. 'Esprit' monitored and controlled electricity during the charging periods, by "shifting some of the charging to off-peak periods or staggered the charging to prevent potential cable overloading issues" (SSE, 2018). One of the significant outcomes was that by adopting an intelligent electrical grid management tool like 'Esprit', the current UK grid network was capable of meeting the additional electrical capacity to charge 30-50% of EVs. It was envisaged that cost saving to SSE would be of the order of at least £2.2bn by 2050.

On the requirement for electricity network upgrades, Element Energy (2015) noted that there was a common view from urban-based energy suppliers that existing substations could supply electricity for new charge point networks; however, there was a need to map the electricity distribution network with a new charge point location early in the process in order to minimize costs related to network connections and/or upgrades. Furthermore, a charging station should be ideally located "within 50m of a substation and availability of a 3-phase mains supply on the right side of the street" should be confirmed to minimize electrical network upgrade costs.

On and Off-street parking

The literature revealed that electrical charging of EVs during off-peak periods would ensure that the grid is not rendered unstable. Overnight charging at homes (i.e. off-street parking) represented a feasible option for most homeowners as costs would be lower by installing slow chargers to refuel an EV in around 8 hours. However, multiple vehicle ownership per home would require additional charger installation (subject to available electricity capacity) leading to higher costs. Interviews revealed that single homes are making way for a block of flats. A higher population density and multiple vehicle ownership per family would evolve into a catch 22-situation as vehicles parked on-street would struggle to refuel overnight. Various stakeholders observed that a challenge facing apartment blocks would be multiple vehicles per apartment. Stakeholders from the City Council argued that for built apartment properties, electrical capacity approved by the planning directorate would inhibit converting all parking bays into EV bays, as each bay was expected to draw at least 10-15 kWh (equivalent to the power requirements of a 1 bedroom apartment). An expensive option would be to secure planning permission and put in new electrical transmission infrastructure. However, the consensus was that publicly owned on-street parking would be more difficult to deal with when compared to privately-owned off-street parking. To overcome issues related to on-street parking, SSE has partnered with Ubitricity (2018) to demonstrate utilizing public lamp posts for EV charging and retrospective billing at Oxfordshire council and cities like Glasgow are monitoring its success.

Glasgow City Council stakeholders indicated that £4.5 million funding was made available to all local authorities from the Office for Low Emission Vehicles (OLEV), a UK government body until 31 March 2020 to install on-street charge points for residents who do not have access to off-street parking. It was pointed out that additional transmission capacity required would limit the number of chargers that can be installed unless new transmission infrastructure was built. From an end-users perspective, it represented a problem of huge proportions and a consensus was met on the above. Apart from issues related to setting up of charging infrastructure, the author noted that stakeholders were skeptical about security issues related to on-street parking overnight, sabotage and secured billing. Vehicles parked on the owner's driveway too would be subject to some or all of these issues.

Funding grants and subsidy support

Availability of funding to demonstrate innovative technologies can be seen as a viable solution in tackling issues concerning the grid constraints. From an industrial perspective it was a 'consensus'

agreement that government support in the form of funding grants was critical to demonstrate new infrastructure based smart grid technologies. Utility providers have to take on a more holistic role by setting up an appropriate infrastructure from a power supply and a distribution perspective. It was observed that securing investment from industry was not an issue; however, the EV rollout presented a chicken and an egg situation. In order for EVs to dramatically expand, consumers require access to the charging infrastructure. Industry, on the other hand, would need assurances of a significant demand for EVs before committing resources to expand the charging infrastructure. Secondly, certain DNOs like SSE or SP Energy networks are exercising a price-freeze promise until 2020 for their customers, thus limiting their ability to invest in new infrastructure upgrade projects.

The UK and Scottish Governments have not committed to providing funding for upgrading the physical electrical network as part of the 2032 targets, as of yet. However, funding is available for developing intelligent grid management services. It was the funding grant from the UK Government that helped SSE to trial a new technology called 'Esprit'. Likewise, the RIIO-T2 stakeholder engagement incentive provided by the UK Government helped Transmission Operators like SP Energy Networks to become more responsive to stakeholder requirements and develop a business plan to deliver a sustainable, efficient transmission network, thus significantly contributing to a low carbon society. From the local authority perspective, there was a 'consensus' that the technology roadmap for attaining EV targets had already been developed by the Government and that the private sector had the initiative to de-risk their future business strategy and invest in setting up of the appropriate infrastructure. The local authorities on their part have already taken a leadership role by building the charging infrastructure and designating a proportion of their parking bays for EVs. An opinion was expressed by many stakeholders that to practice innovative business models like public-private partnerships would provide a breakthrough between the two parties.

4.2. Policy Gaps

Policy barriers were identified as the primary cause for the lack of standardization with industrial stakeholders in full agreement that there were clear policy gaps related to the EV sector and much needed to be done by the national, devolved and local governments across the UK. At the time of interview the policy frameworks setting up new grid infrastructure were not and only published in July 2018 (Road to Zero strategy and Automated and Electric Vehicles act) which is seen as important to provide a clear road map and guide for the localized grid infrastructure. It was pointed that the Scottish Government had to quickly adapt the recent legislation on Autonomous and Electric Vehicles and the Road to Zero roadmap within its EV policies, in order to achieve its EV targets eight years ahead of UK. The author noted that Glasgow City Council's implementation of LEZs across the city centre in clear phases represents a good example that would force commuters to switch to EVs or use the EV driven mass transit system. End-users interviewed generally were focused on the outcome of policy initiatives (i.e., in the form of incentives), rather than the policy regulation itself. It is true to a greater extent that policy regulations define incentive schemes and it is critical that the confidence of end-users is raised to invest in an EV. For EVs to become ubiquitous, a strong policy initiative towards designating all public parking bays for EVs will force stakeholders to adapt to the new commuting culture.

4.3. User experience

Incentivization

The literature identifies that EV technology is considered to be advanced and hence, the initial cost of uptake has been a major barrier to its adoption. It is similar to other advanced technologies like Solar PV that with economies of scale it is hoped that the price will be comparable to convention fossil fueled vehicles. Incentivization is a popular tool employed by the government and private sector alike to build the economies of scale. Hence, there was a blanket agreement across all stakeholder types that the initial cost of EVs was the main barrier and that incentives should be provided and continued until it is on par with conventional vehicles. Stakeholders from the City Council highlighted that current EV schemes appeared reasonable, such as a lower Vehicle Excise Duties and capital allowance offsets and that local authorities receive further grants to purchase EVs. Industrial focused stakeholders

argued that 'zero' fuel duty on electricity for charging should be considered as a form of incentivization. Secondly, current schemes to support renewables adoption like Feed-in-Tariffs (FiTs), demand-side response and guaranteed localized generation should be continued in the foreseeable future to ensure a balanced equation. During periods of peak electricity demand, car batteries that store electricity for EVs could be incentivized to export electricity to the grid in a Vehicle-to-Grid mode, thereby generating additional revenue for the EV owner. The end-user stakeholders showcased a 'consensus' attitude to the above approach with many adding that further VAT reductions on the purchase of new EV's should also be considered, based on previous successful schemes for new emerging 'clean' technologies. Also, the cost of installing a home slow-charger in 2018 is being incentivized at the rate of 50% of its costs by Transport Scotland and a further 25% by the Energy saving trust. A major concern raised by the end-user stakeholders was that some of the incentives seem to end sooner than 2020. All the interviewees strongly felt that in order for the Scottish government to achieve their set targets by 2032, it should concentrate on providing better incentives to raise economies of scale. It is clear that current incentives by the Government have not motivated conventional vehicle owners from making a switch to cleaner EVs. It would result in a quicker transition if the incentives brought the high price of an EV on par with that of a conventional fossil-fuelled vehicle.

Range anxiety

Range anxiety is a factor that deters every stakeholder from owning an EV. However, the perception on range anxiety is changing considerably. There was a favorable agreement observed for the end-user stakeholders who were of the opinion that EVs were more suitable for shorter commutes within the cities for work (or) young families who generally do multiple stopovers over long distances. For typical city journeys, battery performance over the years has improved immensely and is less of a concern. However, priority should be accorded to identify and install fast chargers at strategic network locations. For a long distance commuter, multiple stops for battery charging need to be very swift to reduce the impact on an already long journey. However, with rapid charging facilities installed at the workplace and across a majority of public spaces in cities, there has been a considerable uptake of EVs in the last few years. The industry stakeholders however felt that the hybrid vehicle was a consideration for overcoming the problem for long distance travelers in the medium term until the infrastructure is in place.

Standardization of the charging fee, identification and billing process

There is currently no standardization followed in the EV charging sector as different stakeholders do not conform to a flat rate structure, and in some instances charged a connection fee on top of the charging fee too. The authors are of the view that this observation corresponds to a policy flaw and that a robust policy framework was required. If employers were to put up the charging facility at workplaces, there was a 'favourable' opinion to accommodate a flexible charging rate corresponding to the peak and off-peak electrical demand. A point raised by more than one stakeholder related to the potential for users to pay a variable rate depending on the time of use, as there was no fuel duty added to using electricity as a fuel. Moreover, with the advent of smarter grids, EV users could become 'prosumers' rather than consumers, by trading excess electricity stored in their EV battery to the electrical grid and make profits during periods of peak demand.

Industrial stakeholders all reflected that standardization was considered key drivers to realize interoperability between different recharging systems. According to the local authority stakeholders, public charging facilities currently offered free-charging; could be phased out to bring the charging rates on par with that of the private sector (when there has been a sufficient uptake of EVs and electricity prices are expected to reduce with the proposed integration of cheaper renewables into the grid). Non-Standardization was identified as a problem in the billing processes needed to be addressed quickly through relevant policy initiatives. Industrial stakeholders detailed that use of smart Radio-frequency identification (RFID) cards, mobile phone / SMS payment (or) direct communication between the car and the charger were popular methods under development. Subscription based services are also in use for drivers who use charging facilities from at the same provider or at the same location. Companies like Ubitricity (2018) have developed smart billing solutions centered on the

public EV charging sector. Using SimpleSocket[Start] charging technology, users could benefit from a mobile electricity meter and a mobile contract by using a standard charging cable that can be integrated into the lamp posts (or) light poles, with authorization and payment realized online via a mobile device. The authors are of the opinion that factors impacting the 'charging culture' would be based largely on the price levels for flexible charging, the convenience factor, cost tolerance and commuting distance. Depending on the available pricing options for on-demand charging, it would naturally force the EV owner to charge during periods of off-peak demand (i.e., overnight) and pay for enough charging during the day to make it home.

4.4. Realistic target?

The final section of the interview was devoted to gathering opinions on the feasibility of attaining the 2032 Scottish transport electrification targets. During this stage of the interview, the authors presented contrasting views from the literature search and other interviewees in order to get a balanced opinion from the respondents. For end users, stakeholders were divided on whether the Scottish Government would achieve its 2023 electrification targets. Most felt that the pace of building the charging infrastructure was inadequate to meet the surge in demand of EV's. Non-Standardization of the current billing process and the need for cheaper electricity prices were other factors that the above stakeholders could relate to (i.e., a favorable opinion was reached, with one of the interviewees who owned an EV concluding that the current billing process seemed fit-for-purpose). Users were of the view that the Scottish government had a long way to go in order to achieve the 2032 targets and their dependency on the UK government would delay the decision-making process, thereby suggesting that it was an *unrealistic* target. However, it was felt that the 2040 UK electrification targets seemed plausible for phasing out new fossil-fuelled vehicles with new EVs.

Industry stakeholders were of opinion that the 2032 target was *achievable,* as long as the government doubled its efforts by providing significant funding and subsidizing the setting up of electric charging infrastructure and new mini- smart grids to support additional electrical generation capacity. Standardization of the charging infrastructure and the billing process would align as long as the regulations dictated it and hence, was not a core issue. Another key outcome highlighted the need for both the government and the private sector to sustain a continued lobbying towards end-users regarding the social, economic and environmental benefits of adopting EVs. From the Local Authority Stakeholders from the City Council argued that the targets seemed *plausible,* due to the clear roadmap provided by the Scottish Government to 2032. The local authorities have taken a pro-active approach by converting most of their buildings and public parking spaces into electric charging bays and are now starting to invest in electrifying their mass transit systems. However, as most local authorities were economically strained, more funding support would be required from the government to convert their entire fleet into electric. The perception, however, was that private sector investment was critical in meeting the 2032 targets potentially opening up PPP funding models.

5. Conclusions

The smart cities agenda offers a huge opportunity to reshape the current transportation infrastructure. Electric vehicles produce net zero emissions during use, thereby providing a sustainable solution to meet the legally binding climate change objectives under the COP 21 (Paris agreement) signed in 2015 by over 195 countries. This research explored whether the Scottish government's ambitious vision to ban new fossil-fuelled vehicles from 2032 and replace them with EVs is achievable, and interviewed 10 stakeholders connected with its delivery in Glasgow. In terms of the hurdles, EV market is still in an evolutionary stage and the high investment costs could render the current technology obsolete. Innovative business models are currently being tested by charging operators, and with some policy support and intensive infrastructure usage, their adoption may become feasible in the near future. Private home charging during off-peak demands is likely to be the low cost and a preferred option for EV owners. It presents an opportunity for Scotland to demonstrate EV adoption ahead of other countries. By committing funding and an appropriate policy framework, Scotland could become a technology hub for EV technologies globally. It would also necessitate a targeted investment towards the EV market from the private sector. The Scottish EV market is evolving at a

faster rate and it is difficult to predict (within a reasonable accuracy) what the future beholds in the next 14 years. The research concludes that reducing the timeline required for meeting the 2032 targets can be met with two important initiatives following initiatives: 1) an action plan backed by an integrated framework to achieve goals under the roadmap and 2) collaboration amongst all stakeholders, backed by robust government commitment is the key to achieve the desired objectives. Whilst the target set by the Scottish Government is ambitious, it is recognized by the stakeholders as a positive step as it is required to drive innovation and facilitate the change.

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